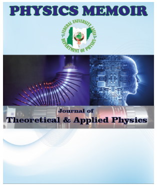

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Original Research

Stitched Transmission Line for On-Body Communication Systems

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Abstract

In this paper we report the use of a stitched transmission line for on body communications. The stitched transmission line was designed as a two wire braided coaxial cable using CST Microwave Studio Suite®. The constructed line is made up of a copper inner conductor surrounded by a polyethylene tubular insulating layer from a stripped $RG174$ braided coaxial cable. For shielding purpose, the structure is stitched onto a denim material with a conductive thread with the aid of a novel presser foot. To explore its suitability for on-body communications, the stitched transmission line was placed at approximately 5mm from the human body at the left hand side of the chest just below the nipple area and measurements were taken with an Anritsu $MS46524A7GHz$ Vector Network Analyser (VNA) for a frequency range of 0.04 – $4GHz$, with measured results demonstrating that the stitched transmission line can be used for on-body communications.

Keywords: On-Body, Wearability, Stitched Transmission Line, Presser Foot, S-parameters

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1. Introduction

Today's textiles materials have come to find lots of applications in virtually all our daily events. Besides wearing apparels all the time and being constantly surrounded with textiles in virtually all our environments, the integration of multifunctional values in such a common material has become a special area of interest in recent years with the use of electronic components on textile materials becoming a major growth area. Textile transmission lines have been developed and used as means of transmitting signals to and from wearable devices with extensive characterization for use in wearable computing applications. With recent advances in wearable communications, the idea of integrating

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antennas and RF systems into apparels worn by humans for On-body communication has been extensively studied as can be seen in [1] - [6].

On body communication refers to a communication system where a set of wearable communication devices are situated inside or around the human body [7]. Usually, on body communications could be wired or wireless,which could include infrared, embedded wiring and Bluetooth technology. However, most wearable devices make use of Bluetooth to communicate, which can be inefficient because of how difficult it is for the signal to pass through a user's body and can cause an effect called "path loss" whereby a signal deteriorates as it travels between two wearable devices, as well as causing security concerns due to the distance the signal travels, with the user being susceptible to eavesdropping [8]. The use of textile transmission lines tends to mitigate some of these deficiencies when transporting RF signals between various pieces of wearable communication systems and also offer a better positioning of an antenna system as antennas tends to perform better when they have a wide field of view of the sky.

Interestingly, there appears to be no published work on the topic in the open literature that specifically addresses wearable transmission lines for on-body communication as most studies are geared towards the use of the human body for signal transmission termed as intra-body communication (IBC) [9] - [15].

In [16], Daniel et al. proposed a stitched transmission line for broadband operation using the idea of a braided coaxial cable. The stitched transmission line like other textile transmission lines functions like the conventional transmission line, but differs from it as it is wearable, lightweight, flexible, washable, robust and comfortable [17] - [18] which makes it a good candidate for on body communications.

In this paper the on body performance of the stitched transmission line proposed by Daniel et al. in [16] is been considered.

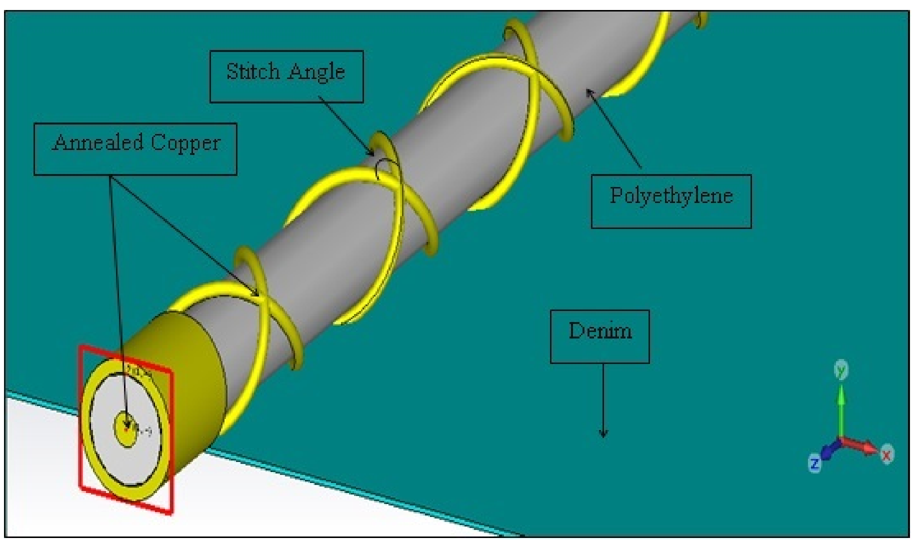


Figure 1. 3-D View of Stitched Wearable Transmission Line Design with CST Studio Suite [11]

2. Stitched Transmission Line Design

The stitched transmission line developed by Daniel et al. in [16] is modeled as a two wire braided coaxial cable with CST Microwave Studio Suit® as shown in Fig 1. This consists of an inner conductor made up of annealed copper, surrounded by a polyethylene (PE) insulated layer, a double helix annealed copper shield and a denim substrate on to which the stitched transmission line is stitched.

To construct the stitched transmission line, use is made of an RG174 braided coaxial cable. The RG174 braided coaxial cable was stripped of its outer sheet and shield and with the aid with a novel presser foot shown in Fig. 3, the stripped RG174 braided coaxial cable was stitched on a Denim material with its tension set at 4, and stitch lengths and width set at 1.2*mm* and 2*mm* respectively. Usually the choice of a coaxial cable for specific applications involves a concession between RF losses, leakage, overall diameter, weight, flexibility and cost. Hence, despite having a higher signal loss compared to larger diameter cables such as RG58, the RG174 was chosen because of its flexibility and smaller diameter which makes it a good candidate for use with the novel presser foot.

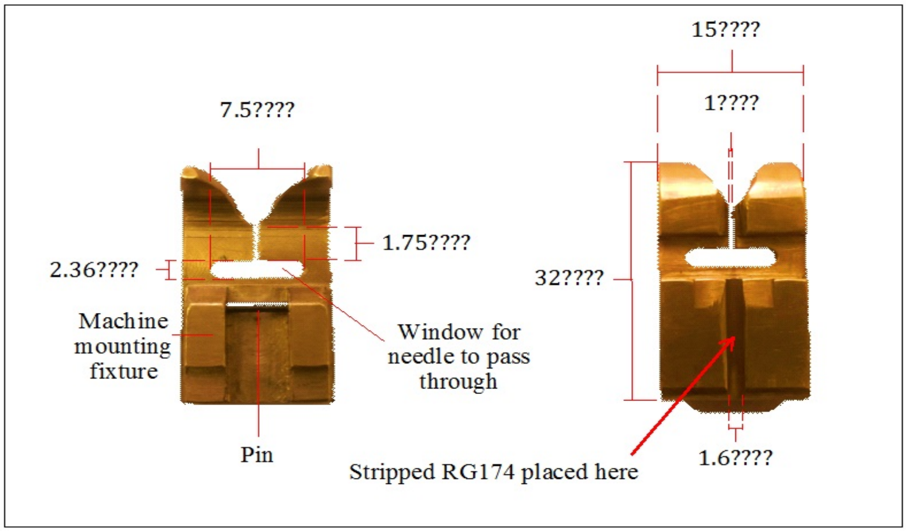


Figure 2. Top and bottom view of the novel presser foot [11]

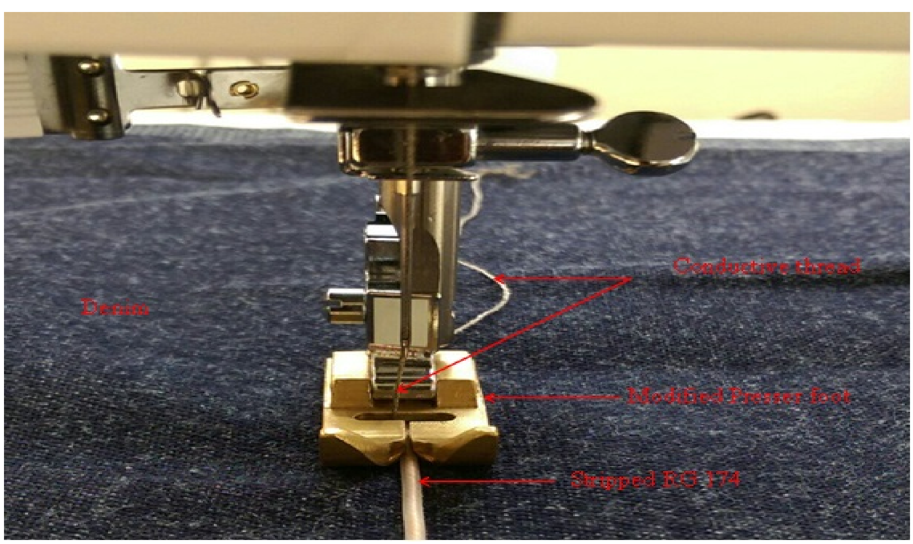


Figure 3. Novel presser foot used with Singer Talent® sewing machine in the fabrication of the stitched transmission line [11]

3. Measured Performance of the Stitched Transmission Line

A flexible stitched transmission line has been built and tested. Fig. 4 shows the simulation and measured transmission and refection coefficient of the stitched transmission line in free space and when placed on the human body. The transmission coefficients S_{21} for simulation in free space are better than -3*dB* for frequencies up to 2.5GHz;-12*dB* for frequencies up to 1.09GHz for OFF BODY and -8.6*dB* for frequencies up to 5.658GHz for ON BODY measurements with the VNA respectively. While the measured reflection coefficient S_{11} for simulation in free space are below

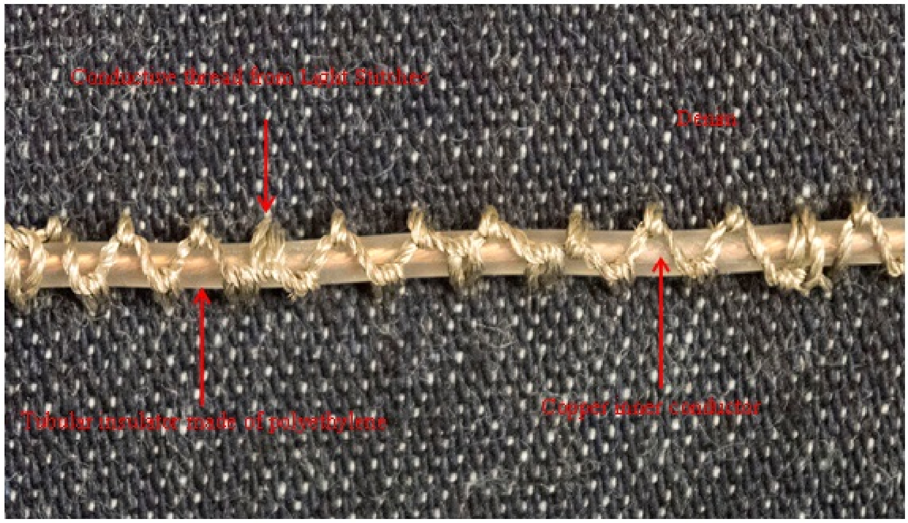


Figure 4. Novel presser foot used with Singer Talent® sewing machine in the fabrication of the stitched transmission line [11]

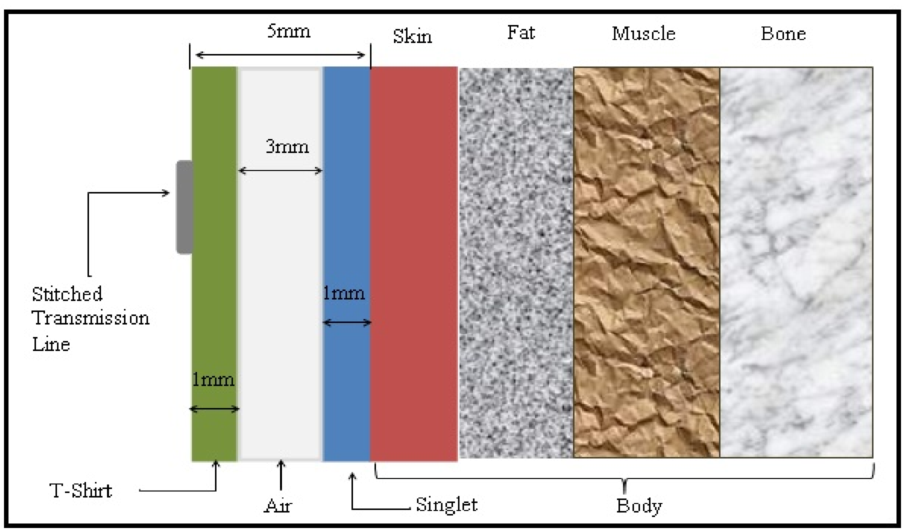


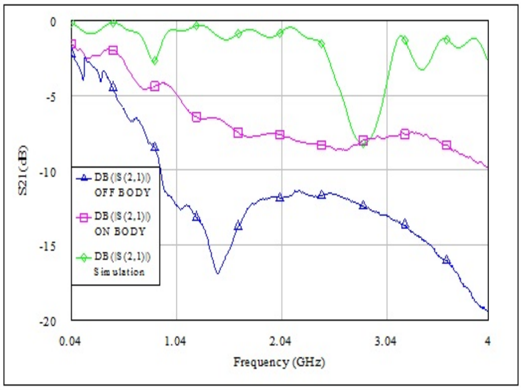
Figure 5. Schematic diagram of ON BODY measurement on the stitched transmission line depicting its proximity to the human body [19]

-5*dB* for frequencies up to 2.55GHz; -6.5*dB* for OFF BODY and -7*dB* for ON BODY measurement with the VNA in the entire operation band. As can be seen from Fig. 4, the immediate proximity of the stitched transmission line to the human body does not have much of an effect on the refection coefficient but yielded a much better transmission coefficient. However some ripples were also observed which are mainly as a result of multiple reflections along the line.

4. Conclusion

Transmission characteristics of the stitched transmission line developed by Daniel et al. in [15] has been presented and discussed for on body applications. The proximity of the stitched transmission line to the human body is seen to have little effect on the reflection coefficient, but yielded a much better effect on the transmission coefficient. However,

Figure 6. ON BODY measurements on the stitched transmission line [19]



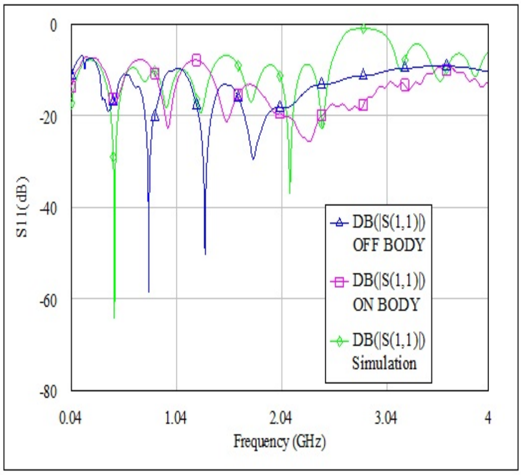


Figure 7. OFF BODY and ON BODY measurements on the stitched transmission line

some ripples were observed at frequencies beyond 2GHz, which are mainly as a result of multiple reflections along the stitched transmission line. Largely, results obtained shows that the stitched transmission line had lower loss when placed close to the human body as compared to the OFF BODY measurements, which makes it a good candidate for wearable applications. However, this study is by no means exhaustive. With the study restricted to the left hand side of the chest just below the nipple area, there's a need to consider placing the stitched transmission line at other body parts and also consider measurements with different body positions and movements.

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